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Ammonium Nitrate for Crop Production

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CONTENTS

THE nitrogen-fertilizer situation in the United States was greatly affected by World War II. We had to meet the enormous nitrogen requirements of our armed forces and those of our allies at a time when our need was greater than ever before for nitrogen for crop production and when shipping difficulties made an expansion of imports of Chilean sodium nitrate impossible. We met these requirements mainly by increasing the production of synthetic ammonia. In 1935, the total capacity for synthetic ammonia in the United States was equivalent to 341,350 tons of nitrogen annually, but by 1944 we had increased this to 1,186,100 tons. Likewise, the Canadian capacity increased greatly. Much of this ammonia was converted into ammonium nitrate for mili-

[1] Acknowledgment is made to R. O. E. Davis, K. D. Jacob, Arnon L. Mehring, Walter Scholl, and Hilda M. Wallace for advice and assistance in the preparation of the manuscript.

tary purposes. By the spring of 1943 the needs of the armed forces were being met and it was then possible to release ammonium nitrate for use in agriculture.

Early attempts indicated the impracticability of using this ammonium nitrate as a fertilizer, because of the tendencies of the material to cake and absorb moisture. Studies were made, therefore, of means for overcoming these difficulties. The efforts were successful. Today large tonnages of conditioned ammonium-nitrate fertilizer containing 32.5 to 33.5 percent nitrogen are being produced. This material is being used satisfactorily both by farmers and by manufacturers of mixed fertilizers.

To acquaint agricultural workers and the interested public with facts on the production, properties, and uses of this new nitrogen fertilizer is the purpose of this circular, which may be summarized as follows.

SUMMARY

Nitrogen fertilizers play an important role in crop production in the United States. Failure to use them would greatly curtail the production of many of our most important crops, including corn, cotton, and other field crops as well as fruits and vegetables. Using them often improves the quality of the crop and increases the yield. The consumption of nitrogen fertilizers has trended upward since about 1933, and this trend was accelerated during the war period. Even without the abnormal requirements of wartime, however, more and more nitrogen per acre is required yearly to take full advantage of the greater yields that are now possible through the use of better cultural methods and improved varieties.

Ammonium nitrate has long been recognized as a potential source of fertilizer nitrogen, but nitrogen from other sources, e. g., sodium nitrate and ammonium sulfate, was formerly less costly. The development of the synthetic ammonia industry removed the obstacle of higher cost. Ammonium nitrate thereafter began to be used in mixed fertilizers in the form of ammoniating solutions and both in mixed fertilizers and for direct application as ammonium nitrate-limestone mixtures and as Leunasalpeter. The use of solid ammonium nitrate as such was still delayed, however, because of the marked tendencies of ammonium nitrate to cake into a solid mass and to take up water. Its reputation as an explosive also hindered its general acceptance.

When, during World War II, ordnance plants in the United States and Canada were able to release large tonnages of ammonium nitrate for fertilizer use, the severe shortage of agricultural nitrogen made it imperative that this source be utilized fully. Research conducted in the two countries on the conditioning and packaging of ammonium nitrate made practicable the use of solid ammonium nitrate for fertilizer purposes. Experience and numerous tests have indicated what precautions are necessary for the safe handling and storage of ammonium nitrate under farm conditions.

Numerous field experiments conducted in widely scattered localities with many different crops have shown that ammonium nitrate is an excellent source of fertilizer nitrogen. It supplies both ammonia and nitrate nitrogen and may be said to perform the functions of both sodium nitrate and ammonium sulfate. Unlike these two materials it

leaves no residue in the soil. Its effect on soil reaction is intermediate between that of sodium nitrate and ammonium sulfate, and, per unit of nitrogen applied, it increases the salt content of the soil solution less than either ammonium sulfate or sodium nitrate.

The nitrogen in ammonium nitrate is low-cost nitrogen. Except for brief periods following their introduction, the ammonium nitrate fertilizers have been so priced that nitrogen in that form costs about the same per unit wholesale as that in ammonium sulfate and considerably less than that in sodium nitrate. Many of the costs of distributing fertilizers to the farmer, as freight, bags, and truckage to the farm, are charged at so much per ton. Such costs are relatively lower per unit of plant food if the material contains more plant food per ton. Conditioned ammonium nitrate, with its 32.5 to 33.5 percent of nitrogen, thus enjoys advantages in distribution costs over sodium nitrate and ammonium sulfate, which contain, respectively, only 16 and 20.5 percent of nitrogen.

Conditioned ammonium nitrate is now widely accepted by farmers and fertilizer manufacturers as a satisfactory source of fertilizer nitrogen. Although first introduced only in 1943, nearly 400,000 tons were used in 1946 for agricultural purposes. There are several reasons for expecting that ammonium nitrate will continue to be an important factor in the fertilizer industry. Among these are its low cost, its high nitrogen content, the improved physical properties of the conditioned ammonium nitrate fertilizers, and the great potential capacity for production in various parts of the country.

CONSUMPTION OF NITROGEN FERTILIZERS

The consumption of commercial nitrogen for fertilizer purposes in the United States increased approximately 50 percent during World War II (fig. 1), despite the requirements of the armed forces. This increase was accomplished largely through the increased production of synthetic ammonia (fig. 2). In 1940, the last prewar year, 419,093 tons [2] of nitrogen were consumed as fertilizer, and in 1941 the figure was slightly greater. In 1942, however, although the demand for fertilizer nitrogen was strong, only 409,000 tons were available because of the necessity for diverting nitrogen to military use. As more synthetic ammonia became available, consumption increased sharply to 509,000 tons in 1943, to 640,000 tons in 1944, and to 679,000 tons in 1945 (preliminary figure). It is estimated that the 1946 consumption reached 730,000 tons.

In the year ended June 30, 1946, seven of the Southeastern States—Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, and Mississippi—consumed 45.8 percent of the commercial nitrogen used for fertilizer purposes in the United States (fig. 3). These seven and California consumed more than half (57.6 percent) of the total. The reasons for the heavy nitrogen consumption in these States are varied, but, in general, it may be said that the nitrogen reserves in the soils are low, also that the farming systems employed return to the soil only a relatively small proportion of the nitrogen removed by crops. Then, too, many of the soils in these areas lose considerable

[2] The 2,000-pound ton is used throughout this circular.

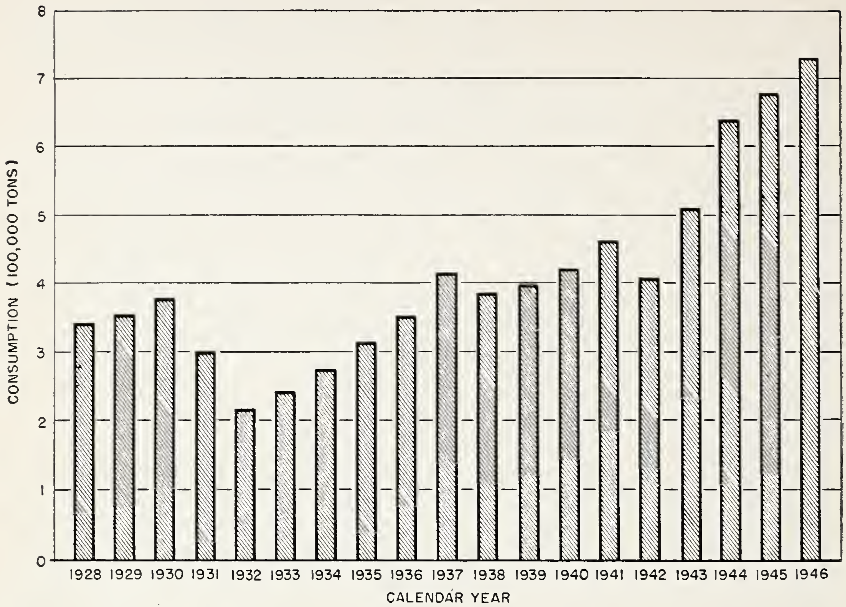

FIGURE 1.—Annual consumption of fertilizer nitrogen in the United States, calendar years 1928–46.

FIGURE 2.—A synthetic ammonia plant constructed during World War II.

nitrogen through the leaching action of heavy rainfall. Without the use of large quantities of nitrogen fertilizers the Nation's supplies of cotton, tobacco, citrus, and other crops grown in these areas would be much less. Even in the Midwest and other areas formerly using little fertilizer, it is increasingly desirable to use nitrogen in crop-production programs. Nitrogen fertilizers thus play a vitally important part in the national economy.

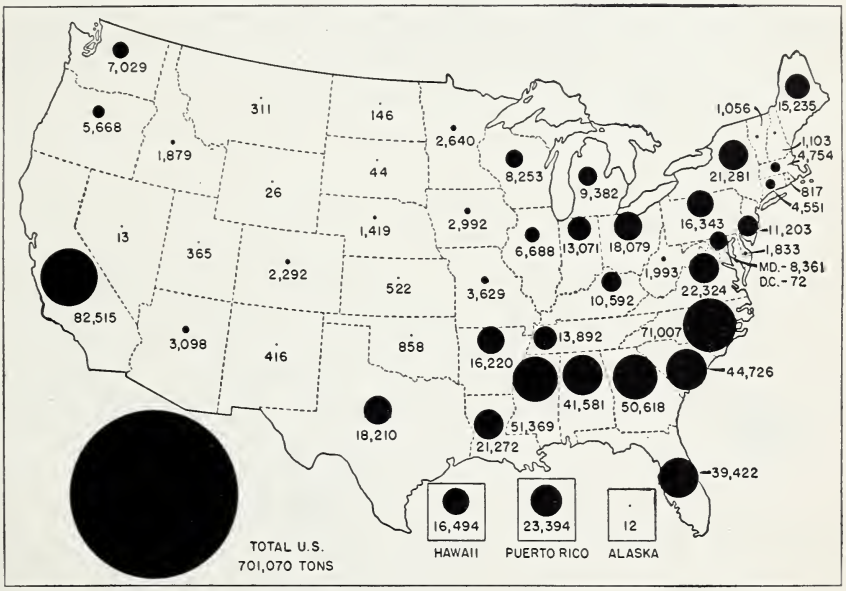

Figure 3.—Geographical distribution of consumption of commercial nitrogen as fertilizer in the United States, year ended June 30, 1946.

Ammonium Nitrate

Except for the ammonium nitrate used in the forms of Cal-Nitro (A–N–L) and as nitrogen solutions, practically none was used in agriculture in the United States prior to 1943. None was reported for the fiscal year ended June 30, 1942, but consumption totaled 57,000 tons in the fiscal year 1943, 314,000 in 1944, 257,000 in 1945, and 384,000 in 1946. Increased military requirements for nitrogen in 1945 accounted for the slightly reduced consumption of ammonium nitrate from the previous year. In the brief period of 4 years the consumption of conditioned ammonium nitrate increased from nothing to nearly 400,000 tons annually. Other large quantities of ammonium nitrate are consumed annually as Cal-Nitro and nitrogen solutions. The latter is the leading form of ammonium nitrate for use in mixed fertilizers.

The distribution of ammonium nitrate to farmers for the year ended June 30, 1946, is shown in figure 4. Of a total United States consumption of 294,565 tons, California consumed 62,674 (21.3 percent); Mississippi 54,896 (18.6 percent); Texas 23,988 (8.1 percent); and Arkansas 16,741 (5.7 percent). The remaining 46.3 percent was di-

vided among the other States and Territories, no one of which consumed more than 5 percent of the total. The use of conditioned ammonium nitrate for direct application was widespread.

The relative importance of ammonium nitrate fertilizer among all the chemical nitrogen fertilizers purchased by farmers in the United States in the year ended June 30, 1946, is shown by the fact that nitrogen as sodium nitrate constituted 35.9 percent of the total; ammonium nitrate, 31.9 percent; ammonium sulfate, 10.1 percent; and calcium cyanamide, 7.6 percent. The rest was divided among several materials. Ammonium nitrate in that year supplied the second largest quantity of chemical nitrogen purchased by farmers, a quantity only slightly less than that supplied by sodium nitrate.

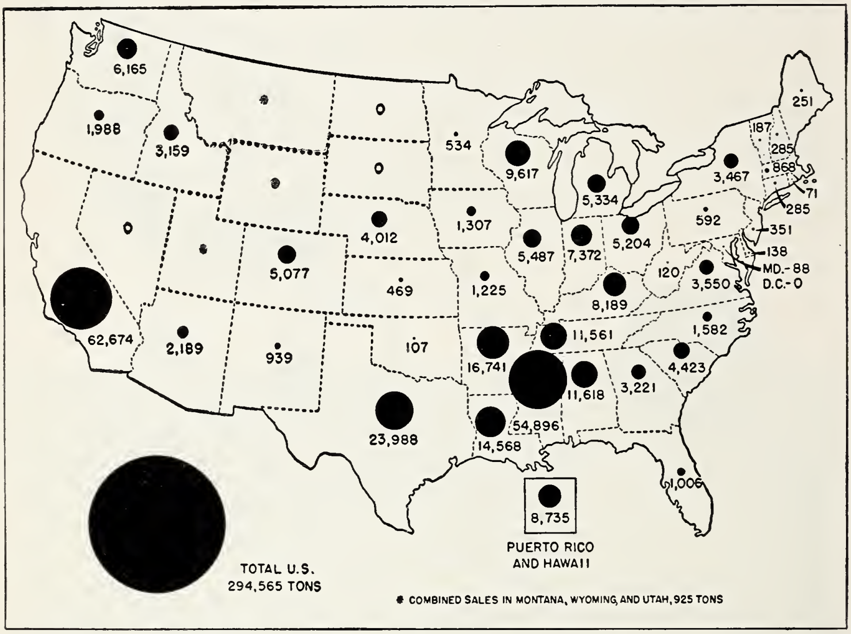

FIGURE 4.—Geographical distribution of ammonium nitrate sold as such to farmers in the United States, year ended June 30, 1946.

IMPORTANCE OF NITROGEN IN CROP PRODUCTION

It has been estimated that the harvested part of 76 leading crops in the continental United States in 1943 contained 5,028,000 tons of nitrogen,[3] about 36 percent of it in leguminous crops. Because of the large quantities of nitrogen removed from the land in crops and other large quantities lost by leaching and in other ways, the maintenance of an adequate supply in the soil is one of the major factors in crop production. Without a sufficient supply plants fail to grow normally and to produce adequately. In severe cases their foliage may become pale or fired at the edges or actual defoliation may occur. The firing

[3] Data supplied by J. H. Stallings, formerly with the former Crop Production Branch, Office of Production.

of lower corn leaves at the tips and along the midribs is typical of a lack of an adequate nitrogen supply for the plant. Even where the foliage of the crop appears normal and fair vegetative growth occurs, the fruit or grain may still be of poor quality if the nitrogen supply is low.

Such vegetable crops as cabbage, kale, lettuce, spinach, radishes, broccoli, and beets usually develop more rapidly and have a better appearance and quality when grown with an ample supply of available nitrogen. On the other hand, too much nitrogen may produce a product that will not stand up well when shipped. In the case of fruit trees, such as apples and peaches, adequate nitrogen is essential for fruit size and yield, but if too much is used the quality of the fruit is likely to be lowered, owing to lack of good color development. Application of nitrogen to pastures and meadows not only improves the yield but also increases the protein content of the crop. A similar increase in protein has been found in wheat.

The problem of maintaining an adequate supply of nitrogen in the soil becomes more acute yearly as improved farming methods and higher yielding varieties permit the harvesting of greater yields per acre. Each increase in yield means that the soil must supply that much more nitrogen if full advantage is to be taken of improved varieties and methods. It has been estimated, for example, that Iowa soils require an additional 30 pounds of nitrogen per acre per year in order to capitalize fully on the new corn hybrids and to maintain the protein content of the grain.

Crop Yields

Numerous experiments by State agricultural experiment stations and the United States Department of Agriculture have repeatedly demonstrated the efficacy of nitrogen fertilizer in promoting crop yields. Representative examples from the numerous data are shown in figure 5. The data for corn are estimated averages from experiments at 11 localities in North Carolina conducted in 1944 with adequate stands of adapted hybrids; those for cotton (seed cotton), are 5-year results on 14 soil types in Georgia and South Carolina; those for potatoes are averages of 2 to 5 years of results in Maine, New York, Michigan, New Jersey, North Carolina, and Pennsylvania; and those for tobacco are results of 6 to 10 years in Georgia, North Carolina, Maryland, and Tennessee with 3 types of tobacco on 5 soil types. All these experiments were conducted under such conditions that the nitrogen supply was the principal factor limiting crop yields.

Comparison of Ammonium Nitrate With Other Nitrogen Fertilizers

The relative merits of the various nitrogen fertilizers have been the subject of numerous experiments. Field studies comparing ammonium nitrate with sodium nitrate, ammonium sulfate, and urea on potatoes have been conducted by the Bureau of Plant Industry, Soils, and Agricultural Engineering in cooperation with the Maine, New York, North Carolina, and Pennsylvania Agricultural Experiment Stations and the Virginia Truck Experiment Station (fig. 6); on cotton, with

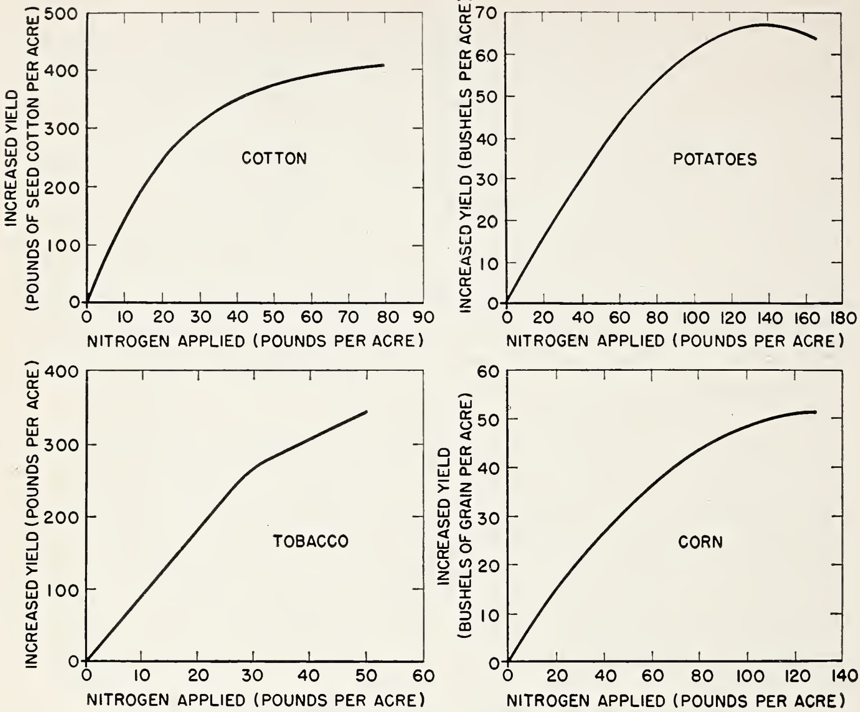

FIGURE 5.—Effect of fertilizer nitrogen on crop yields.

FIGURE 6.—Potatoes grown in Aroostook County, Maine, with ammonium nitrate supplying one-third of the nitrogen—yield, 283 bushels per acre; same quantity of nitrogen but all from other sources, 275 bushels per acre.

the North Carolina and South Carolina stations; on tobacco, with the Georgia, Maryland, North Carolina, and South Carolina stations; and on sweetpotatoes and strawberries, with the North Carolina station. Similar studies were also conducted independently by various agricultural experiment stations. The broad scope of these studies introduced a wide variety of soil, crop, and climatic factors.

Some of the results obtained with corn, cotton, potatoes, and tobacco are summarized in table 1. Ammonium nitrate gave a good account of itself in comparison with other nitrogen sources. A trend equally favorable to ammonium nitrate was shown by other results not included in the table.

TABLE 1.—*Yields per acre of corn, cotton, potatoes, and tobacco obtained from different nitrogen sources used in complete fertilizer*

Source of nitrogen [1]	Corn [2]	Cotton [3]	Potatoes [4]	Tobacco [5]
	Bushels	*Pounds*	*Bushels*	*Pounds*
Ammonium nitrate	39. 2	1, 231	241	1, 039
Ammonium sulfate	37. 0	1, 240	235	962
Sodium nitrate	38. 2	1, 241	232	972
Urea	--------	1, 184	238	([6])

[1] The same quantity of nitrogen was supplied by each material for any given crop, but the rate of application varied with the crop. Phosphoric acid and potash were supplied in ample quantity in all experiments.
[2] Shelled corn, 24-year average, Mississippi.
[3] Seed cotton, average of 19 tests, North Carolina.
[4] Average of 27 tests, Maine, New York (Long Island), Pennsylvania, and Virginia.
[5] Leaf tobacco, 10-year average, Maryland.
[6] In a supplementary 11-year test in Maryland, urea produced an average yield of 931 pounds of leaf tobacco per acre; ammonium sulfate, 868 pounds.

DEVELOPMENT OF AMMONIUM NITRATE AS A FERTILIZER

Prior to the development of the synthetic-ammonia industry ammonium nitrate was produced mainly by adding sodium nitrate under proper conditions of temperature and concentration to a solution of ammonium sulfate. Most of the sodium sulfate formed by the resulting reaction crystallized out, leaving a mother liquor that, when diluted slightly and cooled, deposited crystals of ammonium nitrate.

When the cost of ammonia fell, because of the large-scale production of synthetic ammonia, the above process was abandoned in favor of the currently used method by which ammonia is oxidized to oxides of nitrogen in the presence of a catalyst and the oxides are absorbed in water to produce nitric acid. The nitric acid is then neutralized with more ammonia to form a solution of ammonium nitrate. From this solution ammonium nitrate is recovered as a pure white salt by evaporation of the water and crystallization. When dry, this salt contains 35 percent total nitrogen.

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Handicaps

Ammonium nitrate has a strong tendency to cake in storage or in transit from manufacturer to consumer. This tendency is largely the result of its hygroscopicity, that is, its property of absorbing moisture, and of the fact that its solubility is high and changes rapidly with temperature. Ammonium nitrate is more hygroscopic than other commonly used nitrogen fertilizers. At ordinary summer temperatures (about 80° F.) it tends to take up moisture at relative humidities of 60 percent or more, while sodium nitrate and ammonium sulfate do not begin to take up moisture at that temperature below relative humidities of about 74 and 82 percent, respectively. Urea behaves about the same as sodium nitrate. Ammonium nitrate is the most soluble of the solid nitrogen fertilizers and, moreover, the quantity that will dissolve in a given quantity of water is doubled in passing from 32° to 86° F. The solubility of sodium nitrate increases less than a third, and that of ammonium sulfate about 10 percent in the same range of temperature. The quantity of urea dissolved is about doubled for that range, but it is less soluble than ammonium nitrate at either temperature. These properties of ammonium nitrate place it at a distinct disadvantage with respect to other common nitrogen fertilizer materials.

When moisture is absorbed some of the ammonium nitrate dissolves and the particles become coated with the resulting solution. If the temperature drops or if some of the water evaporates, new crystals form between the particles and knit them solidly together, forming a caked mass.

Another consequence of its hygroscopicity is that ammonium nitrate sometimes becomes wet and sticky while being handled in the mixing plant or in the farmer's fertilizer distributor under weather conditions that affect other nitrogen fertilizers less. Ammonium nitrate may also cake, even though remaining essentially dry, through the action of heavy pressure, as in deep piles of bags. Bags of unconditioned ammonium nitrate frequently set so hard that they were once jocularly referred to as "tombstones." Reducing this caked material to such condition that it can be applied directly to the soil or used in the preparation of mixed fertilizers is a tedious operation. The caking tendency and the hygroscopicity have been minimized by recent research and development on the processing and packaging of this material for fertilizer use.

In Europe

In Europe, processes for the fixation of atmospheric nitrogen were in large-scale production much earlier than in the United States. Ammonium nitrate was a logical product of some of these operations, and large tonnages were produced for use in explosives and other products. It was not, however, extensively used for fertilizer purposes, except after further processing, in which it was mixed with other materials.

To obtain the material known in the United States as Cal-Nitro and in Germany as Kalkammonsalpeter, precipitated calcium carbonate is stirred into a hot saturated solution of ammonium nitrate. The resulting slurry is sprayed into a drying chamber to give a granular

product of uniform-size particles. For several years prior to World War II large tonnages of Cal-Nitro were imported into the United States. A similar product manufactured in England is known as Nitro-Chalk. Ammonitre, formerly manufactured in France, contained calcium sulfate instead of calcium carbonate.

The German product Ammonsulfatsalpeter, formerly called Leunasalpeter and once familiar to the fertilizer trade of the United States under that name, is a double salt of ammonium sulfate and ammonium nitrate, $(NH_4)_2SO_4.NH_4NO_3$. It is less hygroscopic than ammonium nitrate. Large quantities of this material are still produced and used in Germany, but it has not been available in the United States since about 1933.

In the United States

Ammonium nitrate was first produced in the United States from synthetic ammonia in nitrogen fixation plants constructed at Muscle Shoals, Ala., during World War I. Interest in the possible peacetime utilization of these plants led to experimental work on the processing of ammonium nitrate for fertilizer use at the Fixed Nitrogen Research Laboratory, Washington, D. C. The plants were closed soon after the war, however, and the work was not carried to conclusion.

After several years of research and development the synthetic ammonia industry expanded into large-scale production with greatly lowered costs of producing ammonia and, consequently, ammonium nitrate. Outlets for both these materials were sought in the fertilizer industry. Ammonia was used directly in fertilizers by allowing it to react with superphosphate, but such use was limited by certain difficulties in handling the ammonia and by the comparatively small percentages of nitrogen that can be added to a fertilizer in this manner. It was found, however, that solutions of ammonium nitrate in ammonia to which a little water had been added were more easily handled and that more nitrogen could be introduced into the fertilizer in the form of these solutions than as ammonia. These solutions, known in the trade as "nitrogen solutions," were introduced in 1935. It was not until 1943, however, that nearly pure, solid ammonium nitrate was manufactured in forms suitable for use as fertilizer. In the same year, the first Cal-Nitro, known also as A–N–L, of domestic manufacture was produced.

PROPERTIES AND KINDS OF AMMONIUM NITRATE

Conditioned Ammonium Nitrate

In order to make ammonium nitrate suitable for fertilizer use it is necessary that it be subjected to treatments that will lessen its tendency to cake and that will reduce the rate at which it absorbs moisture from the atmosphere. Satisfactory methods for doing this were developed during World War II through the cooperative efforts of private producers of ammonium nitrate, the Tennessee Valley Authority, and the United States Department of Agriculture. The treatments used comprise the steps of granulation and of coating the individual particles with a dust either in the absence or in the presence of a water-repellent material. These steps are referred to collectively as condi-

tioning, and the product is called conditioned ammonium nitrate. The research and developmental work on the conditioning of ammonium nitrate for fertilizer use, together with the technical and scientific aspects of the subject, have been fully discussed by W. H. Ross and his coworkers. (See (*19*) of Selected References, p. 28.)

Ammonium nitrate is granulated either by the graining (fig. 7) or by the spraying method. In the graining method the crystallization of the ammonium nitrate takes place in a grainer that stirs the material constantly to prevent the formation of large masses. In the spraying method a concentrated hot solution of ammonium nitrate is sprayed into the top of an enclosed tower and allowed to fall freely through the air. The droplets congeal as they fall. Both methods of granulation produce particles that are roughly spherical in shape (fig. 8) and consist of numerous small crystals knit together closely.

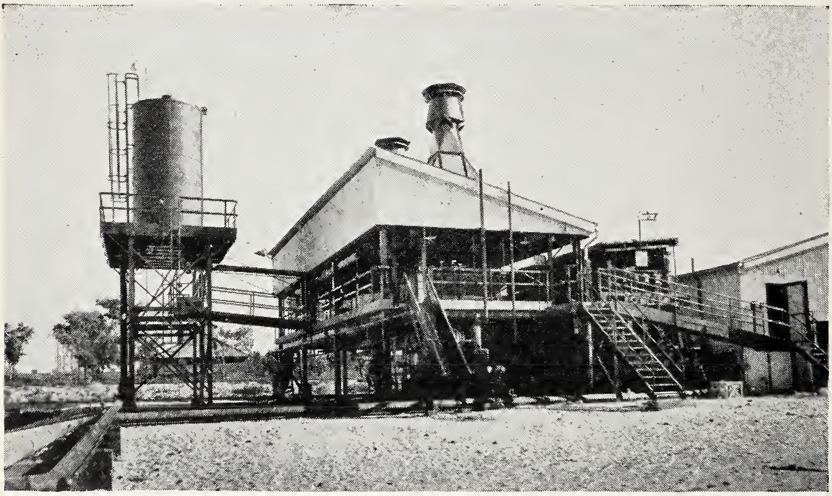

FIGURE 7.—Ammonium nitrate evaporating and graining unit at the plant of the Tennessee Valley Authority.

At some plants, the conditioned ammonium nitrate granulated by the graining process is treated with a mixture of rosin-paraffin and petrolatum that forms a water-repellent coating about each particle. This coating is not used on the spray-granulated ammonium nitrate, but both types are given a coating with at least 3 percent of an insoluble dustlike material, such as kieselguhr or kaolin. This is applied after the water-repellent coating, if such is used.

These treatments reduce caking and hygroscopicity in several ways. The spherical particles have a minimum of surface area on which water may be absorbed, and contact between individual particles is also at a minimum. There are thus fewer points at which the particles may readily knit together. The extent of actual contact between ammonium nitrate surfaces is further reduced by the dust coating that tends to hold the particles slightly apart. The water-repellent coatings assist in keeping the ammonium nitrate dry while it is being applied to the soil or handled in the mixing plant.

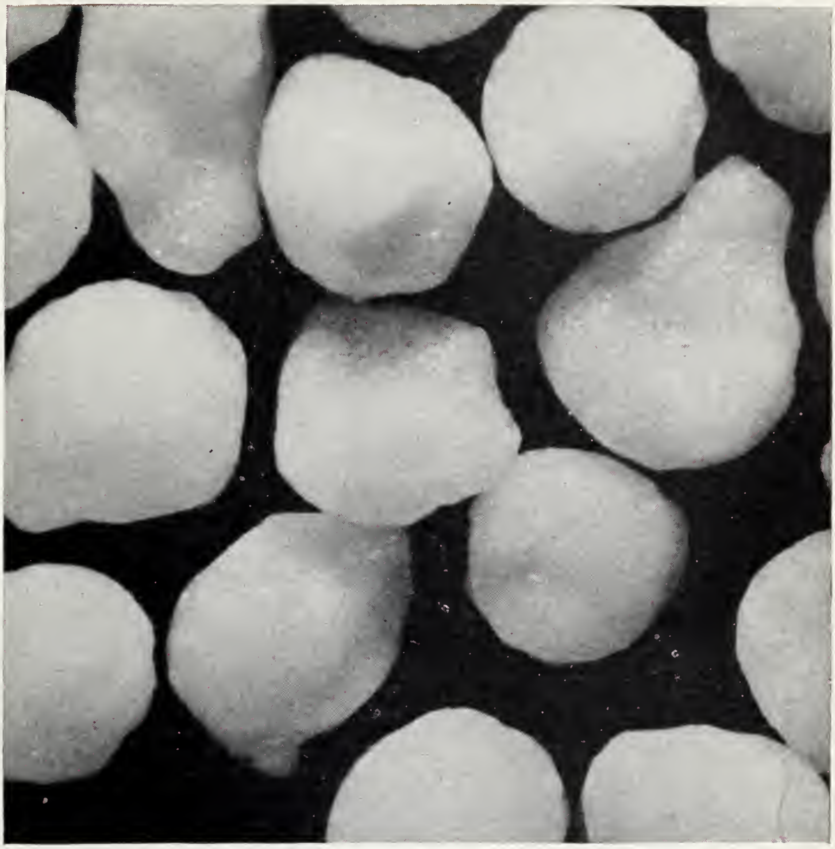

FIGURE 8.—Spray-granulated ammonium nitrate, 8 to 10 mesh (× 16).

For the full protection of conditioned ammonium nitrate against moisture absorption while being stored or shipped under humid conditions, water-resistant bags are required. In general, satisfactory protection is afforded by bags made of five or six plies of heavy kraft paper, one or two of which are asphalt-laminated to make them water-repellent. Such bags are now in general use.

Three types of conditioned ammonium nitrates have been produced commercially and sold. These are marketed under the names ammonium nitrate fertilizer, Herpoco, and Nitraprills. The first two are made by the graining process, and the third is made by the spray-granulation method. The properties of these materials are given in table 2.

Ammonium Nitrate-Limestone Mixtures

Cal-Nitro, or A–N–L, is made in the United States by mixing finely divided dolomite with a hot concentrated solution of ammonium nitrate to form a slurry that is then sprayed from the top of a granulating tower. The spherical granules that collect at the bottom of the tower are first cooled and then dried in a rotary dryer. As a final

TABLE 2.—*Properties of solid ammonium nitrate fertilizers* [1]

Fertilizer	Total nitrogen [2]	Distribution of particle size, mesh basis [3]					Type of granulation	Dusting material	Water-repellent
		>10	10–14	14–20	20–40	<40			
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*			
Nitraprills	33.5	25.8	49.3	12.0	8.6	4.3	Spray	Kieselguhr	None.
Ammonium nitrate fertilizer	32.5	.1	.8	8.1	58.7	32.3	Grained	Kaolin	PRP.[4]
Cal-Nitro (A–N–L)	20.5	79.2	10.4	6.0	2.5	1.9	Spray	([5])	None.
Herpoco	33.0	.3	.5	.7	2.8	95.7	Grained	Kieselguhr	PRP.[6]

[1] The data relate to materials produced in 1943 and 1944.
[2] Half ammonia nitrogen and half nitrate nitrogen.
[3] The screen analyses were made on individual samples. The distribution of particle size is subject to considerable variation from sample to sample.
[4] Petrolatum-rosin-paraffin in the proportion 1:3:1.
[5] Contains admixed dolomitic limestone.
[6] Coated first with petrolatum followed by a 1:4 mixture of paraffin and rosin.

step the granules may be treated with about 5 percent of finely divided dolomite or other dusting agent. Only one grade, that containing 20.5 percent nitrogen, is made in the United States. In this product 40 pounds of dolomite are used with each 60 pounds of ammonium nitrate. Cal-Nitro contains the equivalent of about 7 percent of magnesium oxide and about 10 percent of calcium oxide (lime). The admixed dolomite renders the ammonium nitrate in Cal-Nitro nonexplosive and greatly reduces the fire hazard. Tests conducted with 40–60 calcium carbonate-ammonium nitrate mixtures that simulated Cal-Nitro gave no evidence of violent or explosive reaction even in the presence of organic matter at comparatively high temperature. The properties of a representative sample of Cal-Nitro are given in table 2.

Ammoniating Solutions

Solutions of ammonium nitrate in ammonia can be readily produced in conjunction with the manufacture of ammonium nitrate. It is necessary to merely add more ammonia to the solution formed by the neutralization of nitric acid with ammonia and to adjust the water content. The products known as nitrogen solutions are shipped in tank cars. The properties of the three typical grades of nitrogen solutions now produced and of ammonia liquor and anhydrous ammonia are listed in table 3. The urea-ammonia liquors, nitrogen solutions, anhydrous ammonia, and ammonia liquor constitute the category known as ammoniating solutions. Certain hazards exist in the handling and use of these materials. Persons so engaged should fully acquaint themselves with the necessary precautions that are supplied by manufacturers. At present these materials are not widely used on farms.

Anhydrous ammonia, although widely used in industry, is difficult to handle because of its high vapor pressure. Ammonia liquor (aqua ammonia) does not have so high a vapor pressure, but its use tends to introduce unduly large quantities of water into the mixture in proportion to the quantity of nitrogen that can be added in that form. Nitrogen solutions, like the urea-ammonia liquors, have relatively low vapor pressures, and their water content is small compared with that of ammonia liquor. They are among the most concentrated of nitrogen fertilizer materials. Only urea, Uramon, the urea-

Table 3.—*Properties of nitrogen solutions and of anhydrous ammonia*

Ammoniating solution	Ammonium nitrate	Nitrate N	Ammonium N	Water	Vapor pressure at 104° F.
	Percent	*Percent*	*Percent*	*Percent*	*Pounds per square inch*
Nitrogen solution	65.0	11.36	29.25	13.3	10
Do	55.5	9.62	31.18	18.5	15
Do	66.8	11.65	25.35	16.6	1
Ammonia liquor	0	0	24.6	70.0	11
Anhydrous ammonia	0	0	82.2	0	211

ammonia liquors, an anhydrous ammonia are more concentrated. The ammoniating solutions supply about one-fifth of the total nitrogen consumed as fertilizer in the United States. The major part of this fifth is in the form of nitrogen solutions. The ammoniating solutions are used in the fertilizer industry only for the manufacture of mixed fertilizers containing superphosphate.

EXPLOSION AND FIRE HAZARD

Ammonium nitrate is an ingredient of important military explosives and, moreover, has been involved in several fires and accidental explosions that, in a few cases, were major disasters. These facts have caused many persons to be unduly alarmed over the hazard connected with the use of ammonium nitrate fertilizer on the farm. Actually, under farm conditions, ammonium nitrate in bags can be handled with adequate safety by the observation of a few simple precautions.

The explosion and fire hazards of ammonium nitrate have been the subject of detailed study and experiment reported on by R. O. E. Davis (*4*) and the Interagency Committee on Hazards of Ammonium Nitrate, Fertilizer Grade, appointed by the Secretary of the Treasury.[4] Ammonium nitrate fertilizer is classed as a dangerous oxidizing material, and present regulations require that it be shipped under the yellow label. Labeling as high explosive is not required. If detonated with dynamite or other high explosive, or heated in an enclosed space, as in the hold of a vessel or an unventilated warehouse, ammonium nitrate may explode under certain conditions. Explosions from shock, however, are difficult to produce and their accidental occurrence is improbable. Explosions due to excessive heat generally occur only when large masses are heated in an unventilated space.

When mixed with readily combustible material, such as sulfur and many forms of organic matter, the sensitivity of ammonium nitrate to detonation is increased but not to an extent that creates an explosion hazard under ordinary conditions. The water-repellent coatings, which are organic in nature, increase the sensitivity somewhat and may lower the ignition temperature, but such coated material is safe to handle by observance of the simple precautions noted in the next section.

The presence of large quantities of ammonium nitrate in a burning building tends to increase the severity of the fire, even though in most cases no explosion will result. Thin layers of ammonium nitrate by themselves cannot be made to burn except through the continuous application of heat. Large piles of ammonium nitrate, however, in bulk or in bags, that become sufficiently heated under conditions of confinement and gas pressure may, if ignited, transmit fire rapidly through the mass, possibly resulting in an explosion.

STORAGE AND HANDLING

Two main factors are to be considered in the storage and handling of ammonium nitrate fertilizer on the farm. These are its tendency

[4] United States Treasury Department. report of interagency committee on the hazards of ammonium nitrate fertilizer in transportation on board vessels. (part 1.) 40 pp. [Processed.]

to absorb moisture, making it sticky, and the possible danger of fire and explosion. When placed in moisture-resistant bags, conditioned ammonium nitrate, like sodium nitrate, can be readily stored on the farm without becoming damp. The bags should not be exposed to rain or snow or placed directly on damp floors, such as those of dirt or of concrete resting directly on the soil. Bags once opened should be tightly reclosed unless fully emptied, and the contents of torn bags should be promptly rebagged. All spilled ammonium nitrate should be cleaned up promptly; if allowed to lie about on the bags in humid weather it will absorb moisture, which will weaken the bags and cause further spillage when they are moved.

Ammonium nitrate fertilizer generally does not cake to any important extent in storage but may do so when subjected to excessive pressure. Heavy objects should not be placed on piles of ammonium nitrate fertilizer in bags, and it is best not to pile the bags more than 12 high to avoid possible caking of the lower bags in the pile. If caking does occur, it will usually be slight and the material can be readily broken up. In piling bags of any material it is also necessary to make sure that the floor is not overloaded.

Persons engaged in the manufacture or processing of ammonium nitrate, in its transportation by land or sea, or in its large-scale warehousing should fully acquaint themselves with the hazards met in such occupations. The following precautions should be observed in the handling and storage of ammonium nitrate under farm conditions:

1. Do not smoke or permit smoking or the use of open flames in or near space where ammonium nitrate fertilizer is stored.

2. Keep ammonium nitrate away from explosives and combustible materials of all kinds, especially gasoline, oils, paints, straw, hay, cloth, paper, shavings, scraps of lumber, etc.

3. Store ammonium nitrate in a well-ventilated building to permit ready escape of gases in the event of fire. If large quantities are to be stored for a considerable period, they should be placed in a building removed by several hundred feet from other farm buildings.

4. Do not store ammonium nitrate near steam pipes or near electric wiring.

5. Clean up spilled ammonium nitrate at once and discard if it has become mixed with combustible material. Do not return such contaminated material to the bag. It is safest to discard all spilled ammonium nitrate. This may be done, however, by spreading it on the land, where it will benefit crops.

6. Destroy promptly empty bags that have contained ammonium nitrate. This does not mean that bags emptied in the field cannot be allowed to lie in the open away from buildings until it is convenient to destroy them.

Fires involving ammonium nitrate are best extinguished by the copious application of water. Apply water with a hose from a distance or behind some barricade. The application of hose streams may, by the formation of steam, cause minor explosions that will scatter the burning material. Carbon dioxide, foam, and other extinguishing agents of the smothering type are ineffective because ammonium nitrate provides its own oxygen for combustion. Steam is of no value whatever.

The gases liberated by burning ammonium nitrate are toxic, and fire fighters should be protected by suitable gas masks, especially if it is necessary to enter the building where the fire is in progress.

EFFECT OF AMMONIUM NITRATE ON THE SOIL

Both Forms of Nitrogen Supplied

Ammonium nitrate is readily soluble in the soil moisture, so that its nitrogen content is at once available to plants. Half this nitrogen is in the nitrate and half in the ammonia form. Both forms can be used efficiently by crops. In some cases part of the ammonia nitrogen may be held in reserve in the soil until converted to the nitrate form by nitrification, a process that may require several weeks in cool weather. In a sense, therefore, ammonium nitrate performs the functions of both sodium nitrate, which supplies nitrate nitrogen, and of ammonium sulfate, which supplies ammonia nitrogen.

Nitrate nitrogen moves about readily with the soil moisture, and where water drains from the soil much of it may be carried off. To avoid such losses nitrate nitrogen should be applied at a time when the crop can use it promptly. Ammonia nitrogen, however, tends to be taken up by the soil colloids and to remain in place in the soil until rendered mobile by nitrification or until used by the plant. It is thus often advantageous to apply part of the nitrogen in the nitrate form and part in the ammonia form. Ammonium nitrate supplies both forms.

Soil Reaction

Many fertilizers have a pronounced effect on the reaction of the soil. Ammonium sulfate, for example, tends to make the soil more acid. It has been determined that for each unit [5] of nitrogen supplied, 107 pounds of calcium carbonate (limestone) is required to overcome the acid-forming properties of the ammonium sulfate. Sodium nitrate, on the other hand, tends to make the soil less acid; the quantity required to furnish 1 unit of nitrogen produces about the same effect on the soil reaction as 36 pounds of limestone.

Ammonium nitrate is intermediate between ammonium sulfate and sodium nitrate in its effect on the soil reaction; 36 pounds of limestone are required to overcome the acid-forming tendency of the ammonium nitrate furnishing 1 unit of nitrogen. This is only about one-third as much limestone as is required to correct the acid-forming tendency of ammonium sulfate (table 4). Enough dolomite is added to Cal-Nitro to balance exactly the acid-forming tendency of the ammonium nitrate.

No Residue

When heavy applications of sodium nitrate are made regularly over a long period on most soils, the sodium residue from this salt may cause extensive and unfavorable changes in the physical properties of the soil. Such changes, however, are rare under good soil management. Similarly, the sulfate residue from ammonium sulfate, if in excess of plant requirements and not compensated by liming, is unfavorable in that it tends to bring the soil bases into solution, causing them to leach away more readily. This results in soil impoverishment. Ammonium nitrate, on the other hand, if not applied in excess of the requirements, may be completely consumed by the crop.

[5] 20 pounds, 1 percent of a ton.

TABLE 4.—*Nitrogen content and equivalent acidity of nitrogen fertilizers*

Fertilizer	Nitrogen	Equivalent acidity or basicity (B)[1] in terms of calcium carbonate—	
		Per unit of nitrogen	Per 100 pounds of product
	Percent	*Pounds*	*Pounds*
Conditioned ammonium nitrate	32. 5	36	59
Cal-Nitro (A-N-L)	20. 5	0	0
Sodium nitrate	16. 0	36B	29B
Ammonium sulfate	20. 5	107	110
Cyanamid	22. 0	57B	63B
Urea	46. 0	36	83
Uramon	42. 0	36	75
Nitrogen solution	40. 6	36	73
Do	40. 8	36	73
Do	37. 0	36	67
Urea-ammonia liquor	45. 5	36	82
Anhydrous ammonia	82. 2	36	148
Activated sewage sludge	6. 0	30	10
Tankage, nitrogenous or process	9. 0	34	16

[1] The acid residue of any material, measured in terms of the calcium carbonate required to neutralize it, is called the "equivalent acidity" of the material. Similarly, the basic residue of any material, measured in terms of the calcium carbonate to which it is equivalent, is called the "equivalent basicity."

SALT EFFECT

Germination of seeds may be prevented or established crops may be damaged by the presence of too much dissolved salt in the soil moisture. This is especially likely to occur when heavy band applications are made to crops grown on sandy soils. But fertilizers vary in their effect on the salt content of the soil moisture; some may affect the salt content several times as much as others. This varying tendency is estimated by means of the salt index of fertilizers. In the salt index the tendency of sodium nitrate to raise the salt content is given the arbitrary value of 100 and other fertilizers are then rated on the same scale.

On this scale ammonium sulfate has the value, or salt index, of 69, while that of ammonium nitrate is 105 (table 5). On a pound-for-pound basis, therefore, ammonium nitrate will tend to increase the salt content of the soil moisture more than either ammonium sulfate or sodium nitrate. Ammonium nitrate contains a higher percentage of plant food than either of these other two materials; hence, when furnishing the same quantity of plant food, it actually affects the salt content to a slightly less extent than ammonium sulfate and about half as much as sodium nitrate. Both the latter materials are regularly used without damage by observing proper precautions, such as placing the fertilizer band at a little distance from the seed. Ammonium nitrate can also be used without expectation of injury and with less precaution than is required with sodium nitrate.

TABLE 5.—*Salt indexes of some nitrogen fertilizers*

Fertilizer	Salt index—	
	Per 100 pounds of product [1]	Per unit of nitrogen
Sodium nitrate	100	6. 060
Ammonium sulfate	69	3. 253
Ammonium nitrate	105	2. 990
Cal-Nitro (A-N-L)	61	2. 982
Urea	75	1. 618
Anhydrous ammonia	47	. 572

[1] Except for Cal-Nitro the values given are for chemically pure materials.

USE OF AMMONIUM NITRATE IN CROP PRODUCTION

Conditioned ammonium nitrate is used as a fertilizer in two principal ways—by inclusion in mixed fertilizers and for direct application either at planting time or as a side dressing to supply nitrogen needed later in the season. It is also used in solution, in composts, and in other special ways.

Conditioned ammonium nitrate fertilizers can be used for direct application in much the same manner as other nitrogen fertilizers, such as sodium nitrate. The results of practical experience and of special laboratory and field tests under rather severe conditions of relative humidity and temperature indicate that, unless application is unduly delayed after the bag is opened, the conditioning treatments adequately protect the ammonium nitrate from moisture absorption while it is being applied in the field. In a field test with a divided-hopper drill from which different nitrogen fertilizers could be applied simultaneously, the ammonium nitrate fertilizers were apparently distributed with as much uniformity as sodium nitrate, and no trouble was experienced with stickiness even at 72° F. and 95 percent relative humidity.

METHODS OF APPLICATION

Ammonium nitrate fertilizer can be applied by hand, but for any large area a fertilizer distributor will prove more satisfactory. Special attachments to planters and cultivators are sometimes convenient. In most cases the same equipment can be used for conditioned ammonium nitrate, sodium nitrate, or ammonium sulfate, except that different settings will be necessary to deliver the same quantities of nitrogen per acre. This is because the distributor must dispense different volumes and weights of the materials in order to apply the same quantity of nitrogen and because some materials pass through the dispensing mechanism more readily than others. In order to apply 40 pounds of nitrogen the distributor must dispense about 23 gallons of Chilean sodium nitrate (250 pounds), but about 14 gallons of ammonium nitrate fertilizer (123 pounds) will supply the same quantity of nitrogen.

In applying ammonium nitrate to fruit trees a convenient method is to measure the material by volume. Small pails serve well for this purpose. By conspicuously marking each pail on the inside to indicate the quantity per tree, mistakes can be avoided. In making the application, the material should be broadcast in a broad ring under the outer spread of branches. As ammonium nitrate is soluble in water it can be left for the rainfall to wash it into the soil.

Individual Crops

Cotton is usually fertilized at planting with a complete fertilizer, but further nitrogen is generally added as a side dressing after the crop has been chopped. Ammonium nitrate may be applied for the side dressing at the rate of 80 to 100 pounds per acre.

In corn production in the Southeastern and Southern States, nitrogen is frequently the limiting factor. Most agricultural experiment stations there recommend side dressing with a nitrogen fertilizer when the corn is 12 to 18 inches high. One hundred to 200 pounds of ammonium nitrate per acre will supply the recommended quantity of nitrogen. Recent studies in North Carolina indicate that even more nitrogen can be used profitably (fig. 9). In the Midwest also a growing need for more nitrogen in corn production is becoming apparent.

Wheat, oats, and other small grains give profitable response to spring top dressings of nitrogen in most of the Southern, Eastern, and East Central States (fig. 10). The best rate of nitrogen fertiliza-

Figure 9.—Increased corn yields from ammonium nitrate in North Carolina. Yields of 19.8, 40.2, 59.8, 80.1, and 81.5 bushels per acre (baskets 1 to 5) obtained by side dressing with 0, 123, 246, 370, and 492 pounds, respectively, of ammonium nitrate after an application at planting time of 80 pounds each of potash and phosphoric acid and 98 pounds of ammonium sulfate.

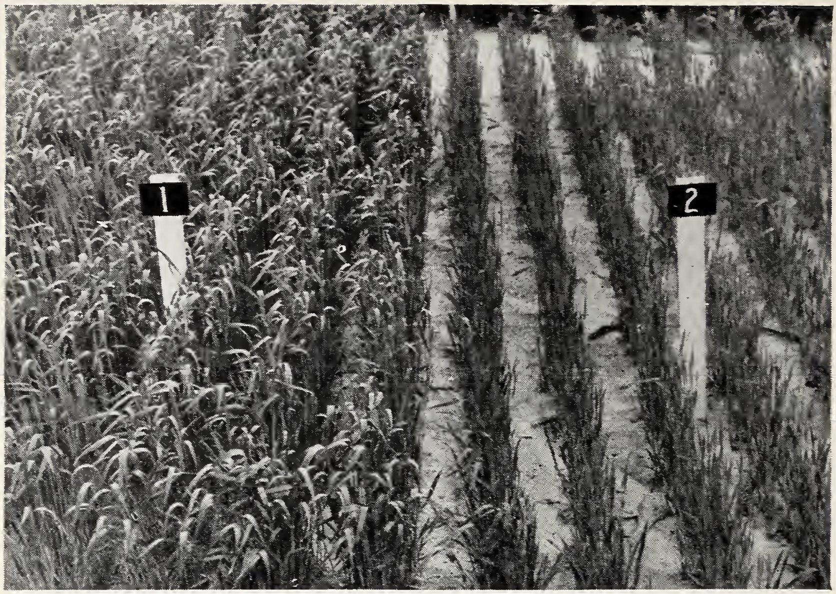

FIGURE 10.—Field demonstration with ammonium nitrate. The wheat at left was treated with 136 pounds per acre of ammonium nitrate fertilizer early in spring; that on the right received no nitrogen.

tion depends on various factors but will average about 20 pounds of nitrogen per acre. Ammonium nitrate fertilizer may be broadcast at the rate of 60 to 200 pounds per acre.

Pastures and hay lands are often profitably top-dressed early in spring with a nitrogen fertilizer in addition to being treated with a complete fertilizer. A top dressing of ammonium nitrate fertilizer at the rate of 100 to 200 pounds per acre helps to increase the growth and protein content of pasture or hay.

Most orchards require regular fertilization for profitable production. Best returns have been obtained from nitrogen fertilizers, but the need for phosphorus and potassium is evident in many orchards, particularly in the Atlantic Coastal Plain and in a few areas elsewhere. As a result, the need for these elements is met by the use of high-nitrogen complete fertilizers instead of some nitrogen material alone. Such fertilizers as 7–7–7, 10–6–4, and 16–10–8 are being used to a considerable extent. The following quantities of ammonium nitrate have been recommended for annual application to apple trees: 1- and 2-year-old trees, 3 ounces; 3- and 4-year-old trees, 8 to 10 ounces; 6- to 10-year-old trees, 1 to 2½ pounds; and trees 15 years and older, 3 to 5 pounds. These quantities are given only as a general guide and should be modified to suit various conditions, as soil type and vigor of tree.

If orchards are being grown in nonlegume sods, the rate should usually be the maximum quantity indicated, whereas under cultivation the minimum rate should prove sufficient. As fertilization is only one of the factors to be considered in fruit production and the use of fertilizers is so closely related to other practices, including proper

methods of pruning, cultivating, and spraying, careful study of the orchard should be made before fertilizers are applied. State agricultural experiment station horticulturists and the county agricultural agents, who have knowledge of local conditions, should be consulted beforehand.

Gardens and Lawns

Ammonium nitrate, in common with sodium nitrate, ammonium sulfate, and urea, is useful for spring applications to garden crops needing an early start, as lettuce, early cabbage, spinach, and kale. Early application of ammonium nitrate is especially important for vegetables eaten raw or as salads and those in which rapid growth, insuring succulence, is desirable. For surface applications, ammonium nitrate should not be placed too near the growing plant and should not be allowed to touch the foliage or stems, as it may cause serious injury to the tissue. After it has been applied it should be worked lightly into the surface soil. Generally it will be advisable to make several light applications instead of one heavy dressing. As ammonium nitrate furnishes nitrogen only, it is desirable to use phosphorus and potassium fertilizers in conjunction with it for garden or truck crops.

For lawns, 3 to 4 pounds of ammonium nitrate may be applied to each 2,000 square feet. This should be done just before rainfall or the lawn should be well watered with the hose immediately after the application. A mixture composed of 3½ pounds of ammonium nitrate with 15 pounds of some organic material, as cottonseed meal, activated sewage sludge, or dried sheep manure, is sometimes recommended for early spring treatment. The mixture should be made only as needed and not be stored, because of the safety hazards.

Composts

In maintaining soil fertility it is essential that organic matter be added periodically as a means of keeping up the supply of humus. Farmers who have barnyard manure, or can grow and turn under green manure crops, or operate on a scale large enough for practicing crop rotation can cope with the problem more readily than the small farmer or the suburban and city gardener. The composting of organic waste materials—leaves, grass and hedge clippings, grass sods, weeds, refuse straw, vegetable trimmings, and other such materials—will prove to be a helpful substitute for hard-to-obtain manure or for the utilization of valuable space for growing green manure crops. Compost piles may be prepared as follows.

Select a level piece of land, preferably in an out-of-the-way spot, with a water supply conveniently at hand, and pack down firmly an area of the size desired for the foundation. A compost pile 4 feet wide by 6 feet long makes a convenient size for the home gardener. Start the pile with a layer of available waste material to a depth of 4 to 6 inches. To this layer add water until well wetted and then scatter a mixture consisting of 1 ounce each of ammonium nitrate, superphosphate, potassium chloride, and ground limestone over the surface. Then cover with 2 to 3 inches of soil and repeat the process until the pile is 4 to 6 feet high, or until the available waste materials are used up. Although inclusion of superphosphate and potassium chloride

usually makes for a better balance of plant nutrients, decomposition of the compost materials will often proceed satisfactorily without them. The compost pile should be depressed in the center to catch rainfall or should be otherwise kept moist at all times.

When large quantities of dry straw are available the following fertilizer materials and lime can be added to each ton:

	Pounds
Ammonium nitrate	40
Superphosphate	30
Potassium chloride	25
Ground limestone	25
	120

The straw is spread out in a pile, layer by layer. Each 6-inch layer is treated with some of the above mixture and moistened. The pile is built up until it is about 4 feet high and is kept moistened during the decomposition process, which in warm weather should be complete in 3 to 4 months.

Humus From Crop Residues

In any soil-fertility program, maximum use should be made of crop residues for maintaining organic matter in the soil. Straw, cornstalks, cotton stalks, and similar material, properly handled, are excellent for this purpose, but are too low in nitrogen to decompose satisfactorily. They will be rapidly converted to humus, however, if readily available nitrogen, as ammonium nitrate, is applied when they are plowed under. The principle is the same as in making composts, but in this case the compost is made not in an above-ground pile but in the soil. Good results have been obtained by broadcasting, before plowing, 60 to 75 pounds of ammonium nitrate for every ton of crop residue.

AMMONIUM NITRATE IN MIXED FERTILIZERS

The use of nearly pure ammonium nitrate as such in mixed fertilizers, a comparatively new practice, has become extensive since conditioned ammonium nitrate became available. Ammonium nitrate has long been used in mixed fertilizers in other forms. As Leunasalpeter it was used as early as 1926 and since about 1930 it has been so used in the form of Cal-Nitro. Since 1935 a considerable tonnage of ammonium nitrate has been introduced annually into mixed fertilizers in the form of nitrogen solutions. The principal problems in connection with ammonium nitrate in mixed fertilizers at this time arise from the fact that, with low-priced conditioned ammonium nitrate widely available, this nitrogen carrier is now often used to supply a larger proportion of the total nitrogen in the mixture than previously.

When nitrogen solutions are used in mixed fertilizers that contain other forms of ammonium nitrate the proportion of this material may become unduly high, with resulting bad physical condition. Such condition may also result from the use of too much sodium nitrate, urea, or other soluble material or from using them in combination with substances with which they are not compatible. In general, mixtures containing ammonium nitrate are not greatly different in hygroscopicity from those containing sodium nitrate.

Excessive development of heat in bulk storage piles of mixed fertilizers or of base goods may be caused by the reaction between the free phosphoric acid in superphosphate, organic matter, and such nitrates as ammonium nitrate. This may result in loss of nitrogen and in the formation of unavailable phosphate in the mixture. In the case of base mixtures composed of poorly cured superphosphates, ammonium nitrate, and organic matter, the reaction, if conditions are right, may develop sufficient heat to induce spontaneous combustion. The reaction may be prevented by the use of well-cured superphosphate or by neutralizing the free acid in poorly cured superphosphate. Where excessive heat development is feared it is best to use smaller storage piles or to build large piles slowly to permit rapid dissipation of the heat. Sprinkler systems equipped with nozzles to furnish large streams of water may be used for the prevention of spontaneous fires. Oxidizable organic matter, such as paper or wood impregnated with ammonium nitrate, should be removed from the vicinity of the stored material, as they may give rise to spontaneous combustion.

Results of research and practical experience on the use of ammonium nitrate in mixed fertilizers formulated with superphosphate and containing 18 to 25 percent total plant food, 2 to 6 percent nitrogen, and 4 to 10 percent potash, indicate that the following points should be observed by manufacturers of mixed fertilizers:

1. All materials should have as low moisture content as is practicable for proper curing of the mixture.
2. Use 25 to 50 pounds (depending on the basicity of the material) of hydrated lime, cyanamide, ammonia, cement flue dust, or other suitable basic material for each 1,000 pounds of superphosphate to neutralize its free acid content.
3. In mixtures containing ammonium sulfate and high-grade potash salts, up to 3 units of nitrogen as ammonium nitrate may be used. This can be in the form of solid ammonium nitrate, nitrogen solution, or a combination of the two.
4. Up to 2 units of nitrogen from conditioned ammonium nitrate may be used in complete mixtures containing urea, ammonia liquor B, ammonium sulfate, and high-grade potash salts.
5. If the fertilizer contains 2 units or more of potash from manure salts, the combined quantity of ammonium nitrate and urea from solutions or solids should not exceed 50 to 75 pounds per ton.

Where local conditions are especially favorable or where the completed mixture can be shipped in moisture-resistant bags, the above limitations may be somewhat relaxed.

COST OF NITROGEN IN FERTILIZER MATERIALS

All fertilizer materials were subject to price control during World War II and in the succeeding period up to November 10, 1946, when the controls were removed. Subsequent to that date some price adjustments have occurred and others will occur. Since solid ammonium nitrate fertilizers were introduced during the war period and since postwar prices are probably not yet stabilized, the relative costs of nitrogen in various materials can best be illustrated by means of ceiling prices.

Except for a brief period following their introduction, ammonium nitrate fertilizers were so priced that nitrogen in that form cost approximately the same per unit wholesale as in the forms of ammonium sulfate, Cal-Nitro (A–N–L), or urea. Nitrogen as sodium nitrate was 27 to 46 cents higher per unit. These relations and others are illustrated in table 6 by means of ceiling and wholesale prices

TABLE 6.—*Wholesale prices per unit (20 pounds) of nitrogen in fertilizer materials*

Material	Nitrogen content	Price [1]
	Percent	
Ammonium nitrate	32. 5	[2] $1. 42
Sodiun nitrate (domestic)	16. 0	1. 69
Sodium nitrate (imported)	16. 0	1. 88
Ammonium sulfate	20. 5	1. 42
Cal-Nitro (A–N–L)	20. 5	1. 42
Cyanamid (granular)	20. 6	1. 63
Cyanamid (pulverized)	21. 0	1. 53
Nitrogen solutions	37. 0–40. 8	[3] 1. 08
Urea	42. 0	1. 37
Urea-ammonia liquors A and B	45. 5	([4])
Anhydrous ammonia	82. 0	[3] . 72

[1] Except as noted, prices are based on OPA ceilings for bulk carload lots at shipping or other price-basing points. Prices may have been higher in some western States.
[2] Based on carload lots of 100-pound bags.
[3] Based on quotation published in May 1946.
[4] On the basis of quotation published in May 1946, per unit of nitrogen the fixed ammonia content was $1.42 and the free ammonia content $0.72.

quoted during the ceiling period. The values in the table are relative and did not necessarily coincide with wholesale prices at given points. Such prices are affected by a complicated system of freight equalizations as well as by other factors. The 1946 wholesale prices of ammonium nitrate fertilizers placed them at no disadvantage compared with most of the other solid nitrogen fertilizers. The relative price situation was not greatly different in August 1947, several months after the controls were removed. Commercial nitrogen in the form of ammoniating solutions, especially as anhydrous ammonia, continues to be the cheapest form for use in mixed fertilizers.

The cost of any fertilizer to the farmer is determined by many factors in addition to the wholesale cost in bulk. Some of these, as bags and bagging, tag tax, freight, and delivery to farm, are based strictly on the number of tons of material handled without regard to the quantity of plant food each ton may contain. Others, including profit to broker, or middleman, and dealer, are stated at so much per ton. Generally speaking, such costs are lower on the basis of a unit of plant food for the more concentrated materials that cost more per ton. The operation of these factors results in considerable advantage to such more concentrated materials as ammonium nitrate and urea, when costs are computed at so much per unit of plant food delivered to the farm.

The extent to which these factors affect prices is seen in table 7, where the average retail ceiling prices per unit of nitrogen in six materials sold to farmers are given for three important fertilizer-consuming areas. Nitrogen in Cal-Nitro (A-N-L) and ammonium sulfate, although costing the same per unit wholesale as that in ammonium nitrate, costs the farmer from 6 to 71 cents more per unit, depending on the locality. The retail cost per unit of nitrogen in sodium nitrate was $0.08 to $1.24 higher than that in ammonium nitrate. Urea, a more concentrated material than ammonium nitrate, supplied nitrogen at costs 22 cents less to 6 cents more than ammonium nitrate.

TABLE 7.—*Ceiling retail prices*[1] *of a unit of nitrogen in fertilizer materials, 1942–46*

Material	Nitrogen content	South-east	Mid-west	New England
	Percent			
Ammonium nitrate	32. 5	$1. 88	$1. 80	$1. 89
Ammonium sulfate	20. 5	1. 92	2. 11	2. 25
Sodium nitrate	16. 0	2. 56	3. 04	2. 88
Cyanamid	21. 0	2. 46	2. 62	2. 67
Cal-Nitro	20. 5	2. 06	2. 51	2. 51
Urea	42. 0	1. 66	1. 86	1. 77

[1] Average of 6 States in each region.

SELECTED REFERENCES

(1) ALLISON, F. E.
1931. THE COMPARATIVE EFFECTS OF CONCENTRATED NITROGENOUS FERTILIZERS ON PERMANENT SOIL ACIDITY. Amer. Soc. Agron. Jour. 23: 878–908.

(2) BROWN, B. E., OWEN, F. B., and TOBEY, E. R.
1930. SOURCES OF NITROGEN FOR POTATO FERTILIZERS IN AROOSTOOK COUNTY. Maine Agr. Expt. Sta. Bul. 354, 38 pp., illus.

(3) COPE, W. C.
1945. CAPACITY TO PRODUCE NITROGEN COMPOUNDS. Chem. and Engin. News 23: 243–246, illus.

(4) DAVIS, R. O. E.
1945. EXPLOSIBILITY AND FIRE HAZARD OF AMMONIUM NITRATE FERTILIZER. U. S. Dept. Agr. Cir. 719, 22 pp.

(5) ——— and HARDESTY, J. O.
1945. ORGANIC MATERIAL AND AMMONIUM NITRATE IN FERTILIZER MIXTURES. Indus. and Engin. Chem. 37: 59–63, illus.

(6) FLETCHER, C. C., MERZ, A. R., and BROWN, B. E.
1940. PRODUCTION AND AGRICULTURAL USE OF AMMONIUM SULFATE. U. S. Dept. Agr. Cir. 578, 15 pp.

(7) HARDESTY, J. O., YEE, J. Y., and LOVE, K. S.
1945. MOISTURE RELATIONS OF MIXED FERTILIZERS. INFLUENCE OF NITROGENOUS MATERIALS. Indus. and Engin. Chem. 37: 567–573, illus.

(8) KING, A. S., NEWCOMB, G. T., and CHENOWETH, O. V.
1943. THE SOLUTION METHOD OF APPLYING AMMONIUM NITRATE. Oreg. State Col. Ext. Bul. 626, 16 pp., illus.

(9) KRANTZ, B. A.
1945. HIGHER CORN YIELDS FOR NORTH CAROLINA. Better Crops with Plant Food 29 (3): 19–22, 48–49, illus.

(10) McMurtrey, J. E., Jr., Lunn, W. M., and Brown, D. [B.] E.
1934. FERTILIZER TESTS WITH TOBACCO, WITH SPECIAL REFERENCE TO EFFECTS OF DIFFERENT RATES AND SOURCES OF NITROGEN AND POTASH. Md. Agr. Expt. Sta. Bul. 358: 255–290, illus.

(11) Mehring, A. L.
1942. CONSUMPTION OF COMMERCIAL NITROGEN AS FERTILIZER IN 1941. Fert. Rev. 17 (3): 2–3, 11–13, illus.

(12) ——— Wallace, H. M., and Drain, M.
1945. NITROGEN, PHOSPHORIC ACID, AND POTASH CONSUMPTION IN THE UNITED STATES, BY YEARS AND BY STATES, WITH PRELIMINARY FIGURES FOR 1944. Amer. Soc. Agron. Jour. 37: 595–609, illus.

(13) Merz, A. R., and Brown, B. E.
1943. PRODUCTION AND FERTILIZER USE OF UREA. U. S. Dept. Agr. Cir. 679, 18 pp.

(14) ——— and Fletcher, C. C.
1940. PRODUCTION AND AGRICULTURAL USE OF SODIUM NITRATE. U. S. Dept. Agr. Cir. 436, 11 pp.

(15) Pierre, W. H.
1933. A METHOD FOR DETERMINING THE ACID- AND BASE-FORMING PROPERTIES OF FERTILIZERS AND THE PRODUCTION OF NONACID-FORMING FERTILIZERS. Amer. Fert. 79 (9): [5]–8, 24, 26–27.

(16) Pitner, J.
1945. COMMERCIAL NITROGEN FOR COTTON, DELTA STATION 1921–1944. Miss. Agr. Expt. Sta. Service Sheet 388, 1 p.

(17) ———
1945. COMMERCIAL NITROGEN FOR CORN, DELTA STATION, 1921–1944. Miss. Agr. Expt. Sta. Service Sheet 387, 1 p.

(18) Rader, L. F., Jr., White, L. M., and Whittaker, C. W.
1943. THE SALT INDEX—A MEASURE OF THE EFFECT OF FERTILIZERS ON THE CONCENTRATION OF THE SOIL SOLUTION. Soil Sci. 55: 201–218, illus.

(19) Ross, W. H., Adams, J. R., Yee, J. Y., and others.
1946. PREPARATION OF AMMONIUM NITRATE FOR USE AS A FERTILIZER. U. S. Dept. Agr. Tech. Bul. 912, 80 pp. illus.

(20) United States Bureau of Plant Industry, Soils, and Agricultural Engineering. Division of Soil and Fertilizer Investigations.
1943. THE USE OF AMMONIUM NITRATE IN MIXED FERTILIZERS. Amer. Fert. 99 (8): 5–7, 20, 22, 24, illus.; (9): 10–11. (Also in Com. Fert. 67 (6): 32–38, illus.)

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